BLACK RHINOECEROS (*Diceros Bicornis Michaelli)* BROWSE AVAILABILITY, SUITABILITY AND ITS INFLUENCE ON DISTRIBUTION PATTERNS AND HOME RANGES OF RE-INTRODUCED RHINOS IN TSAVO WEST NATIONAL PARK – KENYA

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DECLARATION

This thesis is my original work and has not been submitted for an award in any other institution.

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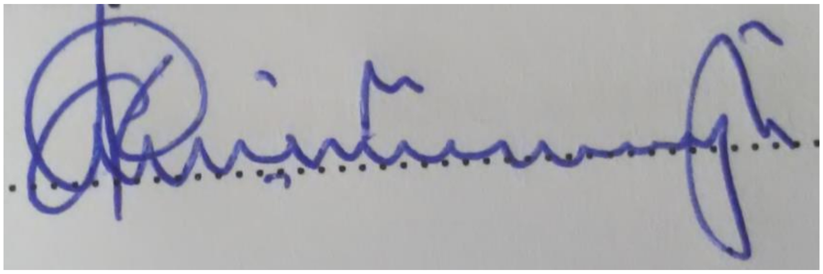
Signature  .Date 21st June 2017

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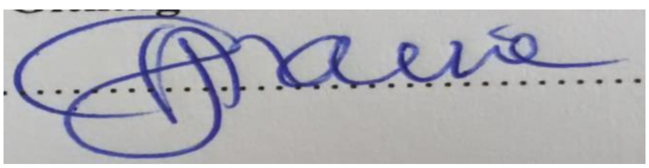
Signature  Date 21st June 2017

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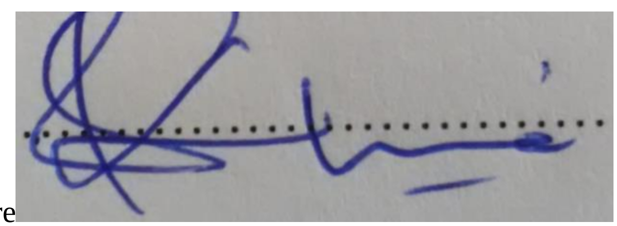
Signature .Date 27th June 2017

DEDICATION

To my wife: Emily Aduvaga, Daughter: Blythe Lung'azo for their love, support and endurance during my course work and preparation of this thesis. To my late father Mr. Joash Tsieri and Mrs. Timinah Lungazo for giving me a better academic foundation and prayers – may your souls rest in peace.

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LIST OF ABBREVIATIONS

ADK	Adaptive Kernel
AfRSG	African Rhino Specialist Group
ANOVA	Analysis of variance
BSc	Bachelors of Science
CITES	Convention of International Trade in Endangered Species and Wild Fauna & Flora
ECC	Ecological Carrying Capacity
GPS	Global Positioning System
IPZ	Intensive Protection Zone
IUCN	International Union for Conservation of Nature and Natural Resources (now called The World Conservation Union)
KWS	Kenya Wildlife Service
MCP	Minimum Convex polygon
PCQ	Point Center Quadrat
RMG	Rhino Management Group
TCA	Tsavo Conservation Area

ABSTRACT

Black rhino home range and distribution patterns in the Intensive Protection Zone (IPZ) of Tsavo West National Park were determined from GPS locations data using Arc View . The IPZ home ranges were categorised into high use area (50 % MCP) and low use area (95% MCP). Home range areas in the Tsavo West National Park - IPZ of 7.5 – 696.4 km^2 (MCP) were larger than many elsewhere. This may in some way indicate a low browse availability or low preferred browse for black rhinoceros, but it is probable that other factors were in play for the higher home range sizes. Home range sizes and distribution patterns of rhinos in the IPZ varied among sexes, seasons and source areas. No difference in home range sizes and distribution of all rhinos in the IPZ for the dry and wet seasons was evident ($t(1) = 2.2188$, $P = 0.2696$ with $P>0.05$). Female rhinos ranged further and had bigger home ranges as compared to male rhinos in the IPZ ($t(1) = 71$, $P = 0.008966$ with $P<0.05$) . Nakuru Rhinos ranged further from their release sites and had larger home ranges during both seasons than Ngulia Rhinos.

Black rhino browse availability (BA) and suitability was studied within Ngulia rhino sanctuary and the surrounding intensive protection zone (IPZ). Plant species suitability rating was determined based on preference ratios. Preference ratings were used to determine and distinguish preferred plant species from those not preferred in relation to rhino utilization. Browse availability in Ngulia, IPZ, IPZ high use and IPZ low use area were then grouped based on suitability/preference ratings.

Browse availabilty was assessed in the 0 to 2 meters primary feeding layer of black rhino over each plot. t- Test was applied to test for differences in browse within and between the two study sites. Plant species diversity and community similarity was also determined and compared in the study sites. Ngulia had a higher browse availability for all plant species and for preferred plant species than the IPZ. A higher diversity of all species and a higher diversity of preferred plant species was found in IPZ than Ngulia. IPZ and Ngulia were found to have a slight similarity in the composition of all species and preferred plant species. There was no significant difference in the BA for high use and low use areas of the IPZ. The high use area was found to have a higher diversity of preferred plant species than the low use area of the IPZ. Higher diversity of plant species and more so of preferred plant species in the IPZ influenced the home range sizes and distribution patterns of rhinos.

CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Essentially, Rhinos are viewed as one of the species that plays a significant role in ecosystem modification and a major revenue earner. In Kenya, the 5-year (2007-2011) strategy for the conservation of the Black rhino marks a shift in the strategy for rhino conservation. This strategy was geared towards conserving at least 2000 Black rhino's in-situ. The strategy recognized that to achieve 2000 Black rhinos as stipulated in the vision will need a shift from the fenced sanctuary system. It is in this regard that the Tsavo West National Park free range habitat needed to be secured and available for the surplus Black rhinos from overstocked sanctuaries. To effectively secure the free-range habitat, extensive research and monitoring was needed. As a step towards this goal, KWS embarked on a long-term project of setting up a free range system of rhino conservation in Tsavo West National Park and referred to it as the Intensive Protection Zone (IPZ). This project was launched in October 2008 when 10 rhinos were captured from a $92km^2$ ring fenced sanctuary within the Tsavo West and translocated to the adjacent IPZ. A further 4 rhinos were captured from the sanctuary in May 2009 and released into the IPZ. In October 2010 the management decided again to reduce the Black rhino population from Lake Nakuru National Park and translocated 10 rhinos from the park to Tsavo west National park. Poaching is still a threat in this area and therefore the management ensured that enough rangers, vehicles, security and monitoring equipment were adequately provided. In the late 1990s, a similar attempt to establish an IPZ in the neighboring Park (Tsavo East National Park) was unsuccessful due to lack of dedicated research involvement. From lessons learnt in this earlier attempt, research has been identified as one of the key pillars of the successful establishment of a free ranging rhino population. Rhinos in Tsavo West were hunted down in the past and the remaining ones were captured in the early 1980s and enclosed in a sanctuary (Ngulia) within the park for protection and breeding. It is from this successful breeding population that the IPZ was formed after intensive research and monitoring of the population performance. The 24 rhinos re-introduced into the main Park area were all fitted with transmitters and ear notched. From the preliminary data collected, differences in distribution patterns and ranging behavior between the rhinos sourced from Lake Nakuru National Park and those from Ngulia within Tsavo West National Park has been noted. This necessitated the study to unravel the differences in distribution patterns. Some of the factors chosen for this study are the rhino browse and watering point distribution. This study intends to investigate whether there is any differences in rhino browse availability and suitability between the sanctuary and the IPZ area. It also seeks to establish whether the difference in distribution patterns and home ranges are influenced by the difference in browse availability and suitability. In this project, food availability and suitability was determined by visual assessment method (Adcock, 2006). Water availability and distribution within the rhino range was mapped by the use of GPS. Radio telemetry data as well as physical sighting with a GPS was used to mark the rhino position. This was then used in the analysis of distribution patterns and home ranges. Rhino ranging area was calculated using the Minimum Convex Polygon (MCP) method. This study was carried out in Tsavo West National Park intensive protection zone and Ngulia rhino sanctuary to test the assumption that a predictable browse availability and suitability exists between the two areas and within the IPZ.

The study was stimulated by various factors: First, the initial population of 14 rhinos translocated from Ngulia rhino sanctuary to the IPZ settled quickly within the release areas and did not roam much as compared to those translocated from Nakuru. Habitat in the Sanctuary is assumed to be similar to that in IPZ as opposed to Nakuru National Park which is predicted to have different habitat from that in the sanctuary and IPZ. Second, there is need to clearly understand factors affecting distribution patterns and home ranges of rhinos translocated from different sources to guide in future re-introductions. Third, there is abundant baseline information for further investigation. Re-establishment of ecologically viable and self-sustaining Black rhino populations in the IPZ is still at relatively early stages, and all of the area’s populations remain fragile and highly susceptible to a number of potential impacts (such as poaching, disease, or intra-specific competition) that could easily undermine the success of the species in the area.

As such, the monitoring and surveillance of all rhino populations, is essential for informing Tsavo Conservation Area (TCA) managers on the overall status and trends in these rhino populations, and as basis for the implementation of management actions.

1.2 Literature review

Black rhinoceros (*Diceros bicornis*) in early 1980's were uncommon outside protected areas due to severe levels of poaching that reduced many unprotected populations (Rachlow *et al.* 1999). In 1970's and 1980's, the rhino population declined both in numbers and range across Africa. By By 1992, black rhino numbers had been reduced to less than 2,500 from more than 65,000 estimated individuals Kenya's Black Rhino numbers were estimated at 20,000 in the 70s but this number reduced to below 300 individuals in the 80s. With the support of conservation partners and the dedication from the security and monitoring teams in rhino areas in Kenya, the numbers have slowly recovered to 631 by end of 2012. Black rhino conservation initiatives have been and will continue to be in danger due to the increased demand for the rhino horn in the illegal market through poaching. IUCN lists the Black Rhino as a critically endangered species emphasizing the need for additional security and other conservation initiatives for its survival. Conservationist globally have been advocating for a range of rhino conservation models that includes Conservation Areas model, Conservancy model, Sanctuary model and IPZ model (Emslie 1994; Leader-Williams *et al.* 1997; Emslie and Brooks 1999 Even though a number of research studies into Black rhino population dynamics and behavior have been done for the free-ranging and sanctuary population (Birkett 2002) continuous research is still required to guide their management and rhino demography and behavior (Rachlow *et al* 1999).

In Kenya, under intensive protection, Black rhino and other herbivore densities have continued to increase within the sanctuaries, to approaching or exceeding Ecological Carrying Capacity (ECC) in some areas, possibly with negative consequences for Black rhino performance. Kenya Wildlife Service (KWS), the state body bestowed with the responsibility of managing Black rhinos in Kenya, has in the past tended to focus on the overall "averaged out" performance of the Kenyan meta-population. As a result, poorer performing populations have perhaps not had as much attention as they should have. Several authorities have suggested translocations, sanctuary expansions, and control of numbers of competing browsers as key technical strategies for improving and maintaining Black rhino population growth (Emslie 1993; SADC-RMG 2001; Birkett 2002; Brett and Adcock 2002). In Kenya rhinos and other competing browsers have been the basis of biological management decisions making anchoring on their ECC (Brett 1988; Foose *et al*, 1992), which need occasional reviews.

1.3 Black Rhinoceros (*Diceros bicornis*)

The black rhinoceros skin color shade ranges from grey, yellow-brown to dark-brown depending on the native soil characteristics. They are known to have two horns with the front horn being longer than the rear one. In some cases, a little third rear horn can be present. horns and occasionally a third small posterior horn is present. The front horn can measure up to 50cm long. Being a browser, the black rhino uses its upper lip to obtain its food. its diet consists of shrubs, trees and herbaceous species

1.3.1 Classification and distribution

The genus *Diceros has only one species which is the Black rhinoceros.* The IUCN standards identify four subspecies and lists all of them as critically endangered**.** In the Southern-central there is the *Diceros bicornis minor).* This sub species was once found in South Africa in the northern and Eastern side, Zimbabwe and Zambia. The arid and semi-arid *Diceros bicornis bicornis* is found on the western side of South Africa, Namibia, Botswana to the west and Angola to the south. The *Diceros bicornis michaeli* had a wide range in Africa but now leading in Kenya in terms of numbers. *Diceros bicornis. longipes* is termerd as most endangered subspecies with remnants only in Cameroon to the North.

1.3.2 Biology, reproduction and social behaviour

Black rhinos are not so social animals and are mostly found alone. Sometimes, groups of two to three individuals (mother and calf or two sub adults or adult male and female) can be encountered in the field. They breed through out the year with varying breeding seasons in different range states and areas. Sexual maturity is about 6 years where as males reach social maturity at around 10 years of age. They carry pregnancy for 16 months and have an interval of between two to three years.

1.3.3 Conservation and population status

Close to 65, 000 plus rhinos were estimated to be in Africa in 1960s towards the end. In 1993 the population of rhinos was estimated at 2,475 in Africa. The 2012 status was reported to be 5,000 individualism Africa the years between1970 and 1980 recorded the highest drop in rhino population across Africa. Rhino numbers in Africa started to stabilize in the year 1992. This was majorly due to the positive contribution from Namibia and South African population. From 1996 the population of rhinos in Africa has steadily increasing and this has been to a larger extend been attributed the positive conservation system in South Africa. The highest rhino population is found in South Africa. Kenya, Namibia and Zambia also rank high after South Africa in terms of rhino numbers. In the earlier 20^{th} Century demand for settlement and agricultural expansion caused a decline in rhino numbers through hunting. However, during the last quarter of the 20th century increased demand for the rhino horn in the far East markets was the major cause of rhino population decline. In the past, in Europe rhino horn was alleged to have the powers to sense poisons. The Chinese and other Asian communities still hold the believe that rhino horn can cure rheumatism and other lifestyle diseases. The wealthy class in Yemen carve and refine the rhino horn into dagger handles used as a symbol of prestige. However, as many people believe, aphrodisiac is not one of the main uses of Rhino horn

1.3.4 CITES Position

Countries worldwide safeguard their black rhino using well defined laws in their respective countries. Even with the laws in place some countries law execution muscles are still low hence threatening the survival the species through poaching in many Nation

1.4 Black rhino browse availability and suitability assessment

When endangered species become confined for security reasons to fenced reserves, the issue of determining the densities that can be sustained by reserve habitats in the long term becomes important. Carrying capacity determination has, however, been a major challenge for wildlife managers, and one fraught with controversy. *Ecological Carrying Capacity (ECC)* in this context is simplified as "the maximum number of animals of a given population supportable by the resources of a specified area" There is no assumption that CC remains constant, except that it is relatively similar within an area over time periods of 3-5 years. Population management of the three-remaining viable black rhino subspecies is aimed at achieving rapid growth of the national herd in each current range country, to achieve viable populations, and to return rhinos to former range countries where possible. For genetic reasons, most states manage their subspecies as one metapopopulation, and swapping of a breeding animal per generation per population is advocated. To enhance population growth rhinos are translocated into new sites at numbers lower than the site CC to reduce social pressure and death resulting from post translocation complications (Emslie and Brooks, 1999). The black rhino populations together with their range need to be managed to maximize reproductive performances, minimize mortality besides maintaining long term rhino browsable material. An understanding of factors determining black rhino densities, distribution patterns and ecological carrying capacities in various local habitats and across

Africa is therefore required to assist in continental, country and protected area black rhino conservation management and recovery.

Black rhino are obligate browsers and can occur wherever dicotyledonous herbs, shrubs and trees exists. the habitations extents wide with annual rainfalls from about 1300 mm down to 100 mm, covering subalpine heathlands, forests, thickets, wooded savannas and deserts. Historically rhinos densities varied significantly ranging from about 1 rhino in every 100 km^2 of Namibian desert (Hearn, 1999) to above 1 rhino in every 1 km^2 in dense bushlands. The highest densities (1.4 to 1.6 per km^2) were found in Tsavo bushlandss, (Goddard, 1970), In contrast, the Mara-Seregeti landscape, supported much lower black rhino densities of 0.04 per km^2 (Frame, 1980).

The use of density and corresponding habitat comparisons across climatic and geological regions to understand patterns of herbivore biomass density has a long history, besides rainfall and soil nutrient status, there is a third critical variable in determining rhino density, namely actual resource availability. The woody component of African savanna areas is highly dynamic and subject to significant vegetation changes from among other things fire, browsing and natural succession (Gillson, 2004). In a given area over time, browse availability can range from abundant to sparse. Actual resource availability and its growth or removal rate could, therefore, be vital in determining total browser and black rhino carrying capacities which may intern influence their distribution patterns within a range.

1.5 Black rhino distribution patterns and home ranges sizes

Resource availability for browsing herbivores is subject to marked seasonal variation in both quantity and quality due to changes in woody plant phenology and chemistry. Therefore, habitat quality for herbivores cannot be estimated purely from production of palatable resources during the wet season but is dependent upon the persistence of alternate vegetation resource types throughout the seasonal cycle; those vegetation components which provide reserve resources during the resource bottleneck in the dry season are particularly important in determining habitat quality (Owen-Smith, 2002).

Browsers in African savannas alter their ranging patterns and reduce their range size during drought period to focus in areas with evergreen species providing important food resources during this critical time of year. Kudu (*Tragelaphus strepsiceros*), for example, foraged in open savanna habitat types during the wet season, utilising forbs in these areas, but contracted their range during the dry season to rocky hills or riparian thickets which included a higher proportion of woody species retaining foliage (Owen-Smith, 1979). Similarly, black rhinos (*Diceros bicornis*) in Ngorongoro Crater in Tanzania, ranged widely during the wet season to feed on legumes in grassland areas, but restricted their movements to riverine areas in the dry season (Goddard, 1967). Riverine areas where woody plant species retain mature green leaves into the dry season have also been identified as important seasonal resources for black rhinos elsewhere (Emslie and Adcock, 1994). Black rhino home ranges may additionally be influenced by social factors (Linklater *et al*., 2010). Male black rhinos are widely expected to maintain mutually exclusive territories after reaching sexual maturity at around eight to ten years (Lent and Fike, 2003). Younger males behave as subordinate or satellite males, overlapping with older territorial bulls (Lent and Fike, 2003). Female black rhinos are not territorial and extensive overlapping of adult female home ranges with both adult males and other females has been recorded (Linklater and Hutcheson, 2010). Females of adult age group, young adults and subadults may links up together for companionship.

Black rhino change in ranges over time with population density fluctuations is still a buzzle (Lent and Fike, 2003) and there is limited understanding of social influences on spatial organisation (Linklater, 2003). Black rhinos are known to be slow to colonize uninhabited areas of reserves (Lent and Fike, 2003) and re-colonization after harvest may be delayed by the disruption of longstanding intersexual relationships (Linklater and Hutcheson, 2010).

1.6 Justification for the study

Efforts to rehabilitate the rhino population in Kenya through increased security and creation of sanctuaries have succeeded. In Ngulia Rhino Sanctuary where initial population in 1986 was estimated at twenty (20) individuals the population has now exceeded the ecological carrying capacity estimated at forty-five causing rhinos to concentrate in the sanctuary and thus exerting pressure on habitat. Creation of sanctuaries has been known to save endangered animals from extinction, but it has been facing challenges as poachers are becoming sophisticated in their mode of operation. Conserving rhinos in sanctuaries is also becoming expensive in regard to the investment required to put up a sanctuary and the running cost in security and maintenance. In Ngulia rhino sanctuary plan, the expansion of the sanctuary has gone beyond its limits and there is no room for more expansion due to physical limitations. The management is, therefore, left with three possible options. One of the options is to drop down the sanctuary fence line and allow the entire rhino population in the sanctuary to roam freely in the park. This was thought to be an uphill task for the management as the ranger force could not be adequate to provide security and monitoring services to cover the entire rhino range. Second option was to establish another sanctuary either within the park or elsewhere and translocate some rhinos from the Ngulia sanctuary to the newly established sanctuary. This option could work but since the management as per its plan is shifting from sanctuary management towards free ranging, decided to go for the third option which was free release (Releasing without first holding the Rhinos in a boma) and free ranging. The study rhinos are part of a founder population re-introduced in 2008 and 2010 to the unfenced area of Tsavo West National Park. As at end of 2013 there were 21 animals in the IPZ having translocated in 24 animals. The initial intention was to have twenty animals released in one go as a founder population but for security reasons and to first understand distribution and anchoring patterns of the initial animals, it was decided that the animals should be released in phases. The first release was of 10 animals from Ngulia sanctuary in October 2008. Ngulia rhino sanctuary is a fenced area located within the IPZ range. The second phase involved four animals in June 2009 again from Ngulia sanctuary, while in the third phase 10 animals from Lake Nakuru

National Park were translocated in October 2010. Lake Nakuru National Park is located 450 km north west of Tsavo West National park.

The seasonal timings, locations and mode of release were considered during the time. The technical team settled on free release of the animals when the drought was almost over at the wet areas with leafy browse material in the rhino valley. This was justified by the facts that the animals would be expected to anchor themselves around the permanent water points. These areas also had sufficient food and shelter. The topography of the escarpment and valleys in the release area was considered very suitable for monitoring animals through a variety of methods including fixed or mobile receivers on high points within the IPZ. Older males and females were targeted in the first batch of capture in order to minimize any risk on the future productivity of source population. Radio tracking devices were fixed on each rhino. each having a different frequency to enable the management to establish their initial ranging patterns. The two populations introduced in the free range have been exhibiting different distribution patterns based on the field observation. Since there was no adequate time to conduct habitat assessment to determine the browse availability and suitability/preference the management felt that this study in addition to other studies done before was paramount for improvement of the IPZ project and other similar future conservation projects

There have been recent scientific studies regarding the relationships between black rhino's home range size, habitat selection, habitat quality and carrying capacity (The direct link between variations in ranging extent and environmental quality was queried by Linklater *et al*. (2010), arguing that changes in animal density alone could allow larger range sizes in an asocial species where overlap of males ranges is governed by intrasexual competition. Linklater *et al*., (2010) criticised the analysis of Reid *et al*. (2007) noting that increased home range size was probably due to the different methods of data collection and analysis and periods of data used. Morgan *et al*. (2009) questioned the applicability of *a priori* estimates of carrying capacity for black rhinos, as habitat selection by black rhinos at three spatial scales didn't have any relationship with the carrying capacity estimates based on measures of total black rhino browse availability (Adcock, 2006).

However, the above studies did not consider the potential influence of browse availability and variation in plant species preference and composition on distribution patterns or habitat selection and ultimately ranging extents sizes for *Dicero bicornis*. By investigating whether distribution arrangements and ranging extents of rhinos released in IPZ in Tsavo West National Park may be influenced by variations in browse availability, plant species preference and composition in the low and high use areas, the study focuses on filling the gap in this area .

Tsavo West IPZ can be classified as "a last fragile conservation effort in the area" being the second pilot project after the one in Tsavo East which did not go well due to lack of science driven management. KWS and its conservation partners have spent a lot of resources to establish a safe and scientifically managed free rhino population in Tsavo West National park. This necessitated credible research work aimed at understanding issues that surround conservation and sustenance of the IPZ as one of our conservation options. The IPZ core zone is an area with adequate watering points and it is also considered as an area with high wildlife densities especially during the dry season. It also lies within a frequently used tourist circuit and hence experiences considerable activities.

The study area contained large predators and elephants and is supplied with a network of man-made and natural waterholes, negating confounding impacts of these factors potentially influencing habitat use. Animals used in this study were released in the same area but at different dates. Sighting data used to generate distribution patterns and home ranges were from both physical and radio signal locations. The study focuses on investigating whether distribution patterns together with home range by black rhinos in the IPZ was influenced by differences in availability and suitability/preference of food resources. This was done by obtaining measures of browse availability (BA) and plant species composition of selected sites within the free range and Ngulia rhino sanctuary.

1.7 Hypothesis

H_o Black rhino distribution pattern and home range in the IPZ is not influenced by browse availability and suitability

1.8 Objectives

1.8.1 General objective

To investigate factors influencing distribution patterns of translocated free ranging Black rhinos in the Tsavo West IPZ, and evaluate success and challenges encountered for the period since inception of the project.

1.8.2 Specific objectives:

The specific objectives were to:

1. Determine IPZ rhinos home ranges plus distribution
2. Compare black rhino browse availability and suitability in Ngulia and IPZ
3. Compare Black rhino browse availability and suitability within the home range areas of rhinos in the IPZ

2 CHAPTER TWO: STUDY AREA

2.1 Location

Tsavo National Park is situated south of Kenya approximately 250 250 km from Nairobi City. The protected area together with its surrounding conservancies approximately 40,000 km² subdivided into two administrative units: Tsavo West National Park, measuring about 9,000 km² and Tsavo East National Park measuring approximately 13,000 km². This study was undertaken in Ngulia rhino sanctuary and section of expansive free range area (Figure 1). The park is located within Taita-Taveta county, and borders both Makueni and Kajiado counties and it lies in ecological zone IV/V

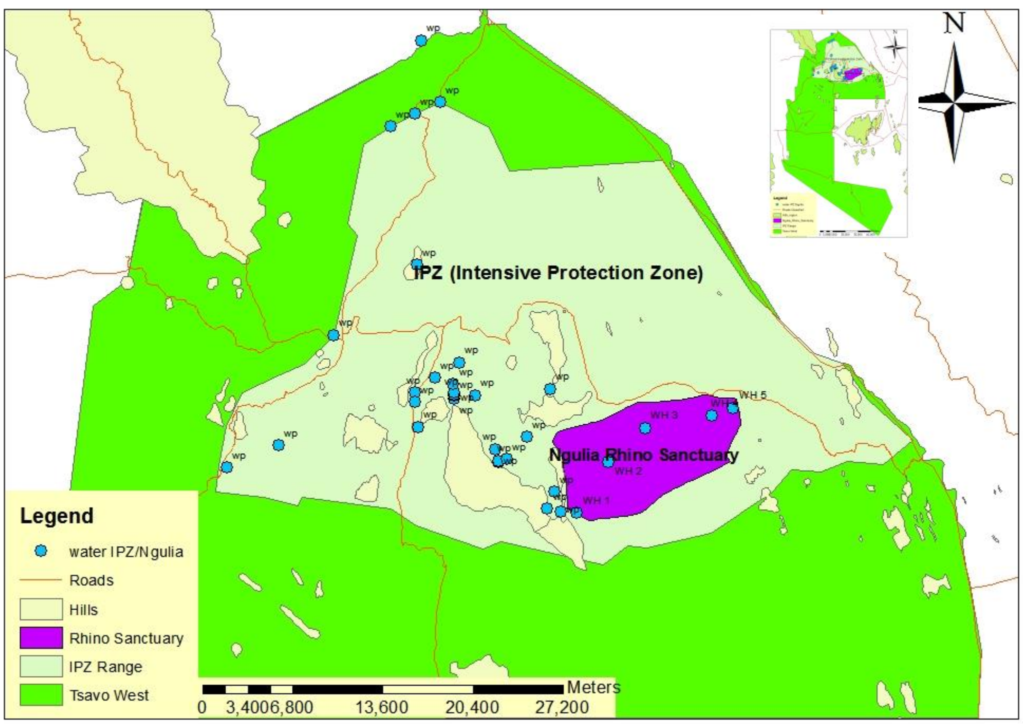

Figure 1: Map of study location in Tsavo West showing Ngulia and IPZ range study sites

2.2 Relief, climate and drainage

The Tsavo area is found slightly to the south of equator. The area experiences two rainy seasons brought about by movements of the Inter Tropical Convergence Zone. The short and long rains in November/December and April/May respectively (Figure 2 and 3). Temperatures ranges from 30^0 C high to 20^0 C low (Wijngaarden, 1985). Rainfall in Tsavo West N.P. averages between 300-600 mm p.a.; with a 10 years drought cycle probable.

Water is scarce during the dry season with heavy habitat degradation in areas around the watering points. Only the Tsavo river flow the entire year. Natural waterholes provide a more widespread water source. Other sources of water are man-made. These includes boreholes (Chyulu, Ndawe, Ngulia), piped water (Mzima pipeline), and numerous dugout waterpans along the game viewing roads. In general, environmental conditions in Tsavo west N.P. can thus be characterised as harsh and subject to extreme fluctuations both within and between years.

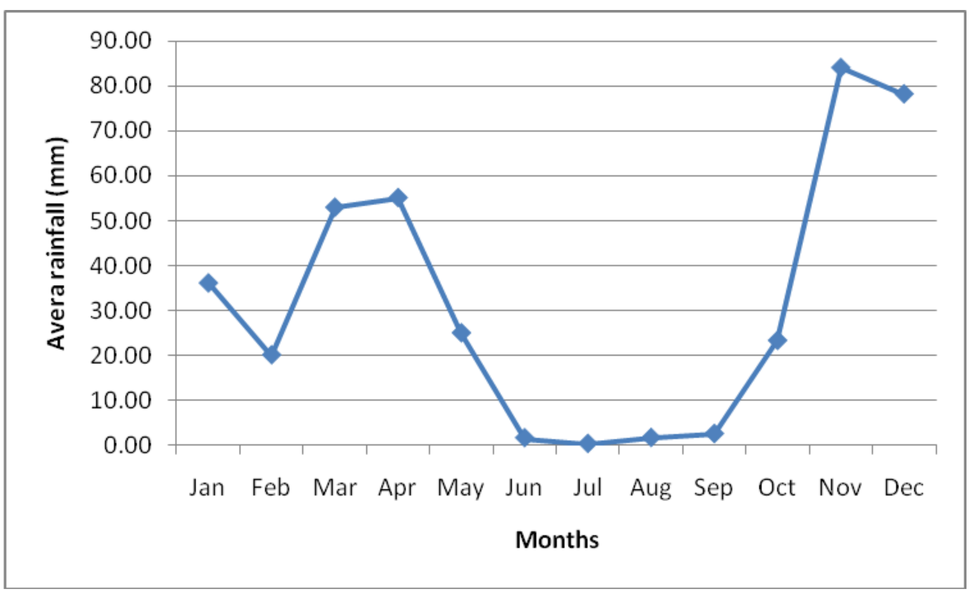

Figure 2: Average Monthly rainfall for Tsavo West Nationa Park from 2000 – 2011

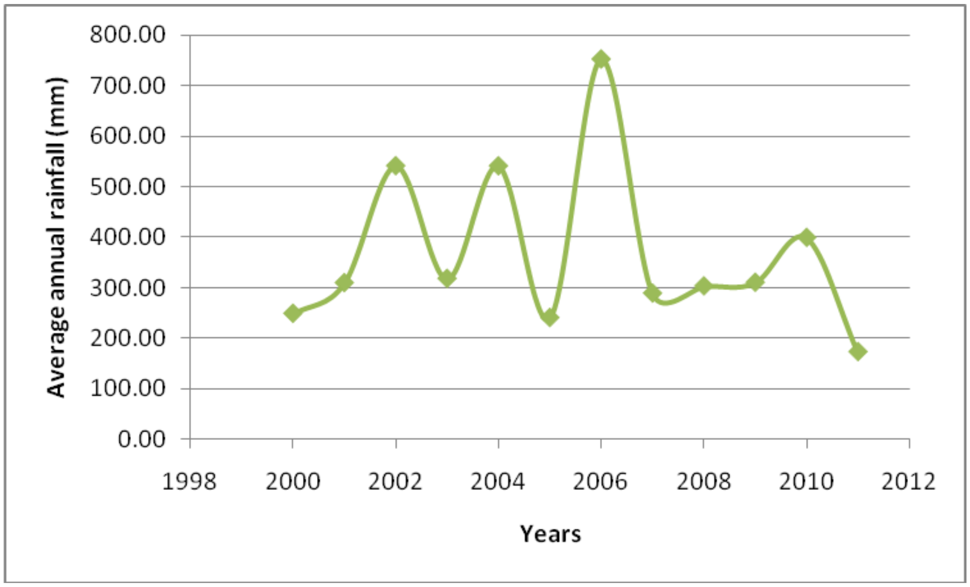

Figure 3: Average Annual rainfall for Tsavo West Nationa Park from 2000 – 2011

2.3 Geology and soils

The geomorphology of the Tsavo ecosystem is mostly of as a result of erosion and sedimention (Wijngaarden, 1985). Below the Chyulu and Yatta are the fragments of older erosion facades (Wijngaarden, 1985). The Chyulu are quite latest volcanic with basalts and pyroclastic materials The Yatta on the other hand has Miocene phonolites on the top and a gneiss rock base. The Tsavo soils exhibit an extensive array in structural, physical and chemical properties.

2.4 Vegetation types

2.4.1 Forest

This habitat consists of riverine or swamp forest types and occurs along the Tsavo rivers . The forest consists of stands of trees, which can attain a height of 18 m... Shruby and herbaceous plants are found on the floor of the forest. Common trees found in this habitat include *Dobera glabra, Newtonia* *hildebrandtii, Acacia elatior* and *Kigelia africana.* Common shrubs include *Azima tetracantha, Capparis sepiaria, Pluchea dioscordis, Salvadora persica, Combretum ukambensis*,. Occasionally, pure stands of *Hyphaena coriacea* measuring about 15m high occur, especially along and on the tributaries of the Tsavo River.

2.4.2 Woodland

This habitat consists of three vegetation layers: the majority deciduous strata of tree as high as 9 m with an 18 m crown, the herbaceous grass strata with bushes. . The common tree species found in this habitat include *Cassia abbreviata, Acacia thomasii* together with *Adansonia digitata* as an occasional emergent. The bush species include *Grewia vilosa, Erythrochlamys spectabilis* and *Euphorbia spp*. The ephemeral grass species include *Aristida spp., Brachiaria eruciformis, Bracharia leersoides, plus Eragrostis caespitosa* .

2.4.3 Wooded grassland

This habitat consists of recurrent herbaceous plants, grasses, sparse shrubby and tree species with greater than 50% of uncovered ground. Grasses in this habitat grow upto 120 cm with varied density and arrangements in space. There are three subdivisions of this habitat which include; The grouped-trees/grassland habitat,of Acacia trees among others,. The scattered-trees/grassland habitat consists of *Melia volkensii tree species among others,* . The shrub components of this habitat include *Boscia plus Balanites shrub species*

2.4.4 Grassland

This habitat consists mainly of grasses mixed with additional herbaceous plant species. Tree and shrubby plant species can sometimes be found in small clusters or individually scattered covering less than 10% of the ground. the sward height ranges from a few centimeters up to about 120 cm. The main grass species include *Brachiaria deflexa, B. leersoides, Aristida adscensionis, Chloris roxburghiana, Tetrapogon* *tenellus* and *Sporobolus helvolus*. The common shrubs in this habitat include *Acacia bussei, Cadaba heterotricha, Combretum aculeatum, Caesalpinia trothae, Caucanthus albidus, Cassia longiracemosa, Ehretia teitensis* and *Thylachium thomasii*.

2.4.5 Bushland

This habitat consists of shrubs or small trees covering above 50% of the ground. Tall trees can also be found in this habitat either individually scattered or clustered together. Herbs and grasses of less than 100cm tall occasionally occur in this habitat. Several different communities of bushes occur in the park and variation in species composition is related to soil type and drainage (Greenway, 1969; Wijngaarden, 1985). In general, the loam soils consist of shrubs and minor tree species such as *Adenia globose, Bauhinia taitensis, Sesamothamnus rivae, Calyprotheca somalensis* and *Grewia fallax*. The sandy clay soils hosts the second community with shrubs and small trees of is composed of *Combretum aculeatum, Dobera glabra, Cadaba heterotricha, Caesalpinia trothae, Acacai tortilis, Sericocomopsis hildebrandtii* and *Ehretia teitensi* among others. The third community, a rather open bushland habitat occurrs on buff-brown sandy loam and includes consists of *Acacia bussei, Acacia mellifera, Boscia coriacea, Combretum aculeatum, Commiphora africana, Cordia monoica* and *Grewia tembensis.* Other common bushland communities include *Bauhinia teitensis thicket, Ochna inermis thicket, Givotia gosai thicket* and *Anisotes parvifolius thicket.*

2.4.6 Wild and domestic animals of the study area

The wildlife mostly found in the region are elephants , buffalo , zebra hartebeest waterbuck gazelle , Impala , hippopotamus , Giraffe , lesser kudu and warthog.

3 CHAPTER THREE MATERIALS AND METHODS

3.1 Vegetation classification and sampling layout

The sampling area was stratified using LandSat images with slight modification by ground truthing. Tsavo West National Park falls within two LandSat 7 scenes (Path 167 Row 062; Path 167, Row063). Two LandSat7 images, both taken during the first dry season of 2010, were acquired for vegetation mapping. The images were imported into Idrisi Kilimanjaro and classified using a hybrid classification method. In hybrid classification, broad vegetation that required identification were identified, defined as information classes. An unsupervised classification algorithm was then used to aid in identifying spectral classes found within the targeted areas. For a defined information class, spectral classes identified in unsupervised classification that fall in the information class were merged, split or discarded depending on the needs, and used to redefining the information class. This process was repeated for all the information classes. The defined information classes were then used to re-classify the image creating a thematic map. Using the Cluster unsupervised classification algorithm in Idrisi Kilimanjaro, 20 spectral classes within each image were defined. Using reference data acquired from the field, these were grouped into 6 information classes (Forested, Woodlands, Thick Bushes, Sparse Bushes, Grasslands, and Swamps). Using selected areas from the generated information classes as target sites, the data was then re-classified using Maxlike supervised classification algorithm in Idrisi Kilimanjaro to generate the final vegetation map.

3.1.1 Browse availability assessment

Browse availability was determined by canopy cover and depth assessment following the browse availability method (Adcock, 2006). In the IPZ, the area was first categorized into high use and low use areas based on the home range analysis. The high use area was considered as the core area or the area where rhinos spend most of their time (That is the 50% contour) and low use as the 95% contour area where rhinos least preferred (Figure 4). Equal sampling plots were established within the areas vegetation types using a random systematic method (Figure 5). Circular plots of five meters radius were used per vegetation type, placed within an interval of 50 meters from each other. The browse availability (BA) was assessed in the 0 to 2 meters primary feeding layer of black rhino over each plot. A light-weight 2m pole, calibrated in 10cm units was used to assist with canopy depth and diameter estimation. In each plot, the volume of browsable material within the 2-m height was estimated. This was achieved by measuring the average height and crown diameter of plant species within the 2-m height in the plot. The number of individual plant species and canopy cover of the plot were also obtained and used in computing the species diversity, community similarity and total volume as shown in section under browse availability and suitability analysis (section 3.1.4).

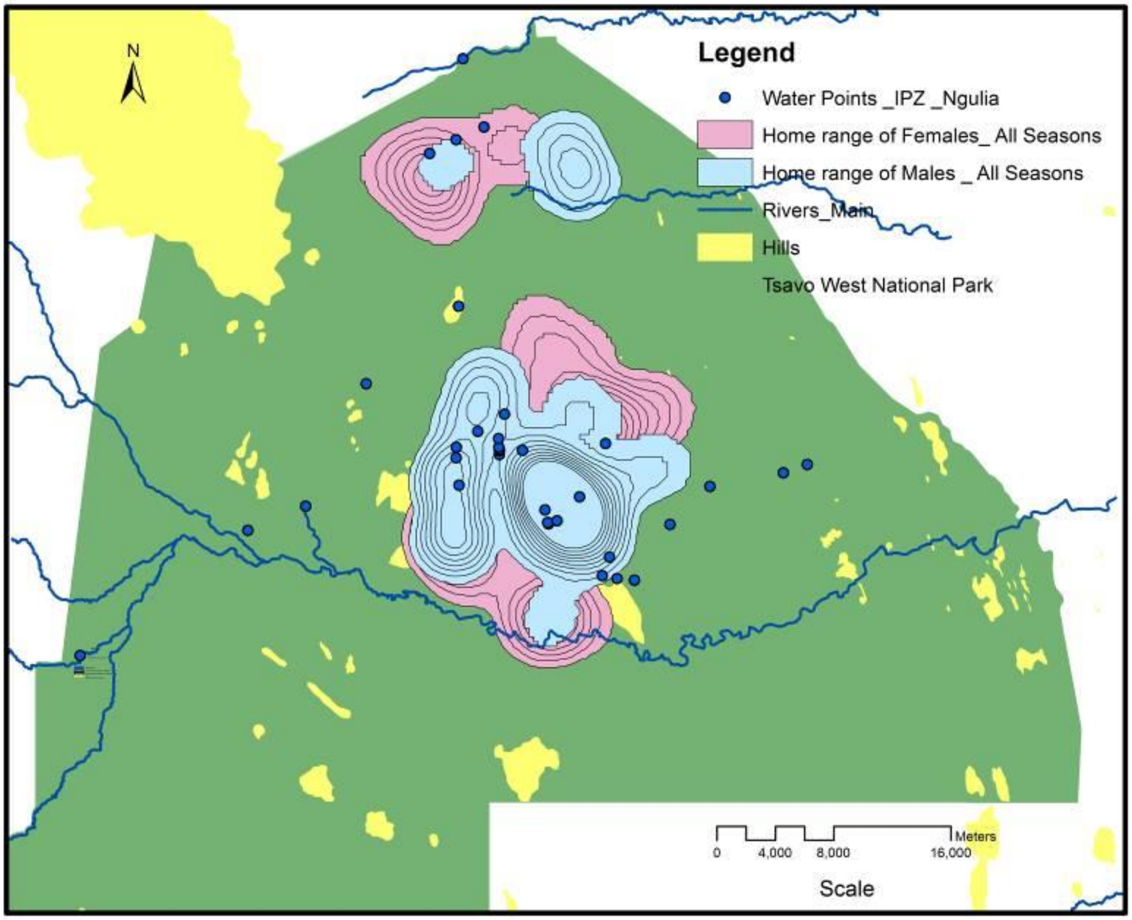

Figure 4: High use area (50% MCP) and low use areas (95% MCP) of the IPZ

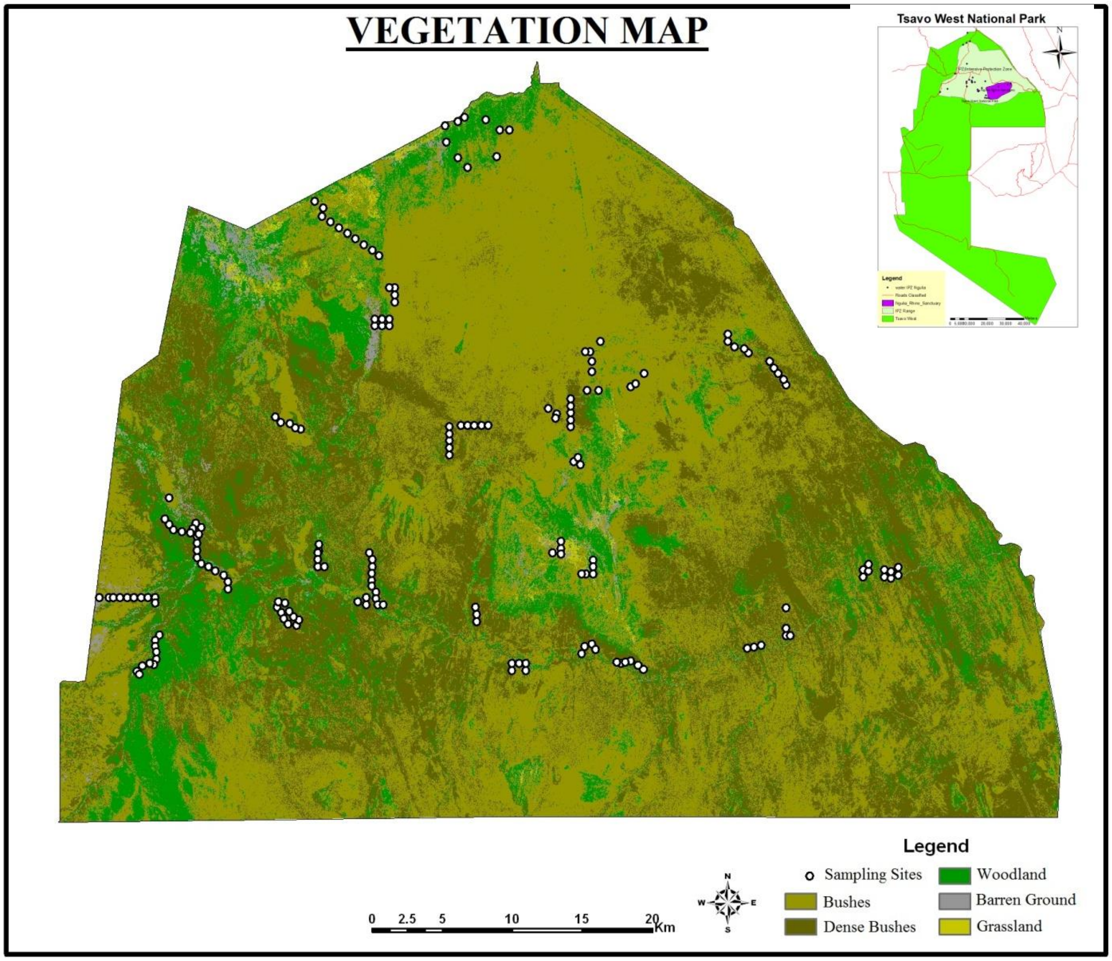

Figure 5: Tsavo West National Park study site vegetation types and Sampling site

3.1.2 Browse selection assessment

Black rhino browse species selection was studied using the backtracking method (Atkinson 1995). With the assistance of a experienced rangers, browsing rhinos were tracked on foot from their favorite places. Once a rhino had been sighted and moved off abit, its foraging track was trailed on foot. Fresh rhino tracks together with rhino bite marks, territory marks, bedding sites and tree marks assisted in track identification . Collection of data started immediately rhino feeding marks were identified. Foraging tracks were divided into 100 m sections by counting 140 observer strides whilst walking (mean stride length = 0.71 m). A distance of 100 m was considered approximately the distance covered by rhino in 30 minutes whilst foraging, hence this formed the equivalent of the 30 minute units considered as independent feeding choices (Owen-Smith and Cooper, 1987b). At each feeding station - each feeding station was 2m wide- (Goddard, 1968) identification of plant species was done, enumerated and information on vegetation utilization by rhino categorization of vegetation offtake by rhino was done in five groups. These groups were as follows; unbrowsed or somewhat browsed; a category of plant species with quarter section taken off; a group with half material fed on; plant material taken off by three quarters and lastly that with all plant parts consumed (Tchamba, 1995). By the use of plant species usage by rhino plant species that were preferred and un preferred by rhinoceros were defined and separated (Tchamba, 1995). A preferred browsable plant species was referred to as that species that was repeatedly utilized by rhino than its great quantity in its neighborhood (Viljoen, 1989). Each plant species preference ratio was determined by dividing the percentage consumed by the percentage available. Plant species utilization by rhinos was represented by bites identified by the characteristic "pruning" of vegetation, where the twig is cut off by the proximal molars leaving a distinctive diagonal cut which was easily detectable (Joubert and Eloff, 1971).

3.1.3 Species preference estimation

Plant species rating was based on preference values. This value helped in identifying and separating preferred species from un preferred by rhinos . Preference ratios for the different plant species utilized by rhinos were calculated using the following equation (Viljoen, 1989).

$$\text{Preferential Ratio (PR)} = \frac{\text{Percentage Utilization (U)}}{\text{Percentage Availability (A)}}$$

Where

$$\text{Percentage Utilization (U)} = \frac{\text{No. of fully utilized plants of a given species per unit area}}{\text{Total no. of fully utilized woody plants of all species within the same area}} \text{X } 100$$

$$\text{Percentage Availability (A)} = \frac{\text{No. of available woody plants of a given species per unit area}}{\text{Total no. of available woody plants of all species within the same area}} \text{X } 100$$

The reference point for the calculated ratio was 1. In this case, the species with values greater than 1 were regarded as preferred by rhinos and were given a grading of 1. A grading of 2 was allocated to species evaded by rhinos as browse and had a preference of ≤1 but >0.5. A value of 3 was assigned to species attaining a ratio greater than 0 but less than 0.5 with species that were completely shunned by rhinos had a ratio of 0. (Table 1) (Ishwaran, 1983; Viljoen, 1989).

Table 1: Black Rhino Plant Species Preference Rating in Tsavo West National Park

Plant species	**% Utilization (U)**	**% Availability (A)**	**Preference Ratio (U/A)**	**Species Rating**
Grewia similis	3.843466	1.89295	2.03041	1
Grewia nematopus	1.956674	0.979112	1.998416	1
Carphalea glaucescens	1.816911	0.913838	1.98822	1
Acalypha fruiticosa	1.74703	0.913838	1.91175	1
Grewia tembensis	4.192872	2.349869	1.7843	1
Barleria taitensis	4.402516	2.806789	1.568524	1
Grewia villosa	3.633823	2.415144	1.504599	1

Barleria eranthemoides	3.354298	2.284595	1.468224	1
Hibiscus micranthus	4.262753	2.937337	1.451231	1
Asparagus racemosus	1.956674	1.697128	1.152932	2
Cassia abbreviata	1.118099	0.979112	1.141952	2
Blepharis linariifolia	1.537386	1.370757	1.12156	2
Albizia anthelmintica	0.978337	0.913838	1.07058	2
Dombeya rotundifolia	0.908456	0.913838	0.99411	2
Ruellia patula	0.908456	0.913838	0.99411	2
Caesalpinia sp	0.838574	0.848564	0.988228	2
Combretum exalatum	1.537386	1.631854	0.94211	2
Hymenodictyon pervifolium	0.838574	0.913838	0.91764	2
Lonchocarpus eriocalyx	0.419287	0.456919	0.91764	2
Grewia bicolor	1.886792	2.088773	0.903302	2
Commiphora campestris	0.55905	1.240209	0.450771	3
Commiphora baluensis	0.489168	1.109661	0.440827	3
commiphora sp	0.279525	0.652742	0.428232	3
Commiphora africana	0.55905	1.370757	0.40784	3
Prectranthus sp.	0.209644	0.522193	0.401468	3
Cordia sp.	0.279525	0.718016	0.389302	3
Commiphora shimperi	0.628931	1.631854	0.385409	3
Premna resinosa	0.489168	1.305483	0.374703	3
Lippia javanica	0.209644	0.587467	0.35686	3
Cyphostemma spp	0.279525	0.78329	0.35686	3
Maerua kirkii	0.279525	0.848564	0.329409	3

3.1.4 Browse availability (BA) and suitability analysis

Browse availability (BA) was derived from three basic parameters: plot canopy cover, plant species canopy area and species canopy depth within the 0-2m space. Data for a given plant species was entered into excel sheet. Total canopy area of that species was derived by calculating the crown area of the species using the formula πr^2 then multiplying this with the number of species in that plot. Canopy depth/height (h) for each species was also measured in the 0-2m layer to give vertical fill. BA was then calculated using the cone shape formula (volume = $1/3\ \pi\ r^2\ h$) to give the volume of browse material of that particular species in the plot. Each species BA was then multiplied by the plot cover to give the final BA value of the species. BA was assessed for all individual browse species in a plot and then totaled for the entire plot: The sum of all (BA's) of all the browse species was regarded as the BA (BA) for the plot. Species preference estimation was then used to sort out BAs for the preferred plant species as described in section 3.1.3. This enabled the grouping of BA of the most preferred plant species. Different analysis was then conducted to compare browse availability and suitability within the IPZ and Ngulia rhino sanctuary.

3.2 Rhino home range sizes and distribution patterns

Table 2: Black rhinos translocated from Ngulia and Nakuru into Tsavo West National Park, IPZ

Rhino Name	RhinoID	Age (yrs)	Sex	Source
CHRIS	042	30	Male	Ngulia
SIMON	051	24	Male	Ngulia
AMAYO	5034	11	Female	Ngulia
Miss GOSS	5042	10	Female	Ngulia
TERRY	5041	8	Female	Ngulia

MARIA	5049	6	Female	Ngulia
ADAN	5016	15	Male	Ngulia
BRETT	5018	13	Male	Ngulia
BAKARI	5029	12	Male	Ngulia
NG'ANG'A	525	23	Male	Nakuru
OKUKU	580	6	Male	Nakuru
OKOTH	586	4	Male	Nakuru
MILKA	590	4	Female	Nakuru
MATU	595	4	Female	Nakuru
BENJAH	600	3	Male	Nakuru
IREEN	605	3	Female	Nakuru
NYANKE	607	4	Male	Nakuru
CHEROTICH	610	4	Female	Nakuru

Initially all the rhinos (Table 2) were located through transmitter signal by the use of radio receiver to avoid disturbances during the settling down period after release. Each rhino was trailed on foot and sometimes using a vehicle with transmitter device until the highest signal possible was received from the transmitter on the rhino. For each signal, the rhino identification, date, time and GPS location were recorded. Latter when the animals settled down further locations were collated by locating and identify each of the rhinos at least once per week. Individual rhinos were detected from spoor, dung or transmitter signals then followed until the rhino was located. Information was recorded following the standardised monitoring procedure of Adcock, K. and Emslie, R.H. (2003) identifying the individual based on earnotches and recording date, time, GPS location within 20 – 50 m, body condition and behaviour or activity during the sighting. Sighting records for the year were combined for analysis as Lent and Fike (2003) recommended use of sample sizes of 35 or more when calculating black rhino home range sizes.

3.2.1 Rhino home range and distribution analysis

Daytime rhino GPS points of the rhino were imported into 3.2 version of ArcView software and established a 95 percent and 50 percent kernel home range (KHR) to show the utmost range extent (Worton, 1989) for individual rhino, using the animal movement extension system (Hooge *et al*., 1999). The probability that an individual or group of rhinos was located in a particular site was indicated by the contour lines. The 95 percent line of contours represents the entire home range where as 50 percent indicated the core areas. A minimum of 10 individual sighting of 12 rhinos were used in this analysis. Rhino sightings were categorised into different groups based on sex, season, sex and season, source, source and season to enable comparison of distribution patterns and home ranges at different levels. Latter on the core area used by each rhino as its home range for comparison was extracted.

4 CHAPTER FOUR RESULTS

4.1 Comparison of mean browse availability (BA)

A paired t-test was conducted to compare BAs in Ngulia and IPZ and within the IPZ itself. BAs in Ngulia, IPZ, IPZ high use and IPZ low use area were latter on grouped based on suitability/preference ratings as described under section 3.1.3. Several t- test were then conducted on two corresponding BAs between Ngulia and IPZ and within IPZ to find out whether there were any significant differences.

4.1.1 Comparison between mean BA in Ngulia and BA in IPZ

A paired sample t-test was conducted to compare BA difference in Ngulia and IPZ. There was a significant difference in browse availability for Ngulia (μ= 107.3, SE= 15.0) and IPZ (μ =51.9, SE= 12.4) t (29) = 3.0636, P = 0.004689 with P<0.05. The results suggest that there is higher browse availability in Ngulia than in the IPZ.

Table 3: Browse availability difference for Ngulia and IPZ

Habitat	N	Mean browse Volume (M^3) μ	Std. Error Mean
Ngulia	30	107.3	15.0
IPZ	31	51.9	12.4

4.1.2 Comparison between mean BA of preferred plant species in Ngulia and IPZ

A paired sample t-test was conducted to compare BA difference of preferred plant species in Ngulia and IPZ. There was a significant difference in the browse of preferred plant species for Ngulia (μ = 23.9, SE= 4.8) and IPZ (μ =10.4, SE= 3.8) t(27) = 3.0946, P = 0.004551 with P<0.05. The results suggest that there browse availability of preferred plant species in Ngulia is higher than that in the IPZ

Table 4: Browse difference for preferred plant species for Ngulia and IPZ

Habitat	**N**	**Mean browse Volume (M^3) µ**	**Std. Error Mean**
Ngulia	30	23.9	4.8
IPZ	31	10.4	3.8

4.1.3 Comparison between BA for high and low use area of the IPZ

A paired sample t-test was conducted to compare BA difference in high and low use areas of the IPZ. There was no significant difference in the BA for high use (µ = 55.4, SE= 20.9) and low use (µ =47.6, SE= 11.6) $t(11) = 1.1483$, $P = 0.2752$ with $P>0.05$. The results suggest that the browse availability in the high use and low use areas of the IPZ is similar.

Table 5: Browse availability difference for the IPZ high and low use area

Habitat	**N**	**Mean browse Volume (M^3) µ**	**Std. Error Mean**
High use area	17	55.4	20.9
Low use area	14	47.6	11.6

4.1.4 Comparison between mean BA for preferred plant species for high and low use area

A paired sample t-test was conducted to compare the difference in BA of preferred plant species for high and low use areas of the IPZ. There was no significant difference in the BA of the preferred plant species for high use (µ = 4.4, SE= 1.5) and low use (µ =10.4, SE= 6.5) $t(11) = 1.1483$, $P = 0.2752$ with $P>0.05$. The results suggest that the browse availability of preferred plant species in the high use and low use areas of the IPZ is similar

Table 6: Browse difference of preferred plant species for high use and low use areas of the IPZ

Habitat	**N**	**Mean browse volume (M^3) µ**	**Std. Error Mean**
High use area	16	4.4	1.5
Low use area	12	10.4	6.5

4.1.5 Comparison between mean browse of preferred plant species in Ngulia and high use area

A paired sample t-test was conducted to compare the difference in BA of preferred plant species for Ngulia and high use area of the IPZ. There was a significant difference in the BA of preferred plant species for Ngulia (µ =23.9, SE= 4.8) and high use area of the IPZ (µ = 4.4, SE= 1.5) $t(15) = 2.8132$, $P = 0.01311$ with $P<0.05$. The result indicates that the two areas exhibit difference in browse availability of preferred plant species with Ngulia having more preferred browse than the IPZ high use area

Table 7: Browse difference of preferred plant species for Ngulia and IPZ high use area

Habitat	**N**	**Mean browse Volume (M^3) µ**	**Std. Error Mean**
Ngulia	30	23.9	4.8
IPZ high use	16	4.4	1.5

4.1.6 Comparison between mean browse of preferred plant species in Ngulia and low use area

A paired sample t-test was conducted to compare the difference in BA of preferred plant species for Ngulia and low use area of the IPZ. There was no significant difference in the BA of preferred plant species for Ngulia (µ = 23.9, SE=4.8) and low use area of the IPZ (µ = 10.4, SE= 6.5) $t(11) = 0.99189$, p-value = 0.3426, $P>0.05$. The result indicate that the two areas are similar in terms of browse availability of preferred plant species

Table 8: Browse difference of preferred plant species for Ngulia and IPZ low use area

Habitat	N	Mean browse Volume (M^3) μ	Std. Error Mean
Ngulia	30	23.9	4.8
IPZ low use	12	10.4	6.5

4.1.7 Comparison between mean BA for Ngulia and high use area of IPZ

A paired sample t-test was conducted to compare the difference in BA for Ngulia and BA for high use region of IPZ. There was no significant difference in the BA for Ngulia (μ =107.3, SE= 15.0) and BA for high use area of IPZ (μ =55.4, SE=20.9), t (16) = 1.2788, P- value =0.2192 thus P>0.05. The result indicate that the two areas are similar in terms of browse availability

Table 9: Browse difference for Ngulia and IPZ high use area

Habitat	N	Mean browse Volume (M^3) μ	Std. Error Mean
Ngulia	30	107.3	15.0
IPZ High use	17	55.4	20.9

4.1.8 Comparison between mean browse for Ngulia and low use region of IPZ

A paired sample t-test was conducted to compare the difference in BA for Ngulia and BA for low use area of IPZ. There was no significant difference in the BA for Ngulia (μ = 107.3, SE=15.0) and BA for low use area of IPZ (μ =47.6, SE=11.6), t (13) = 1.5678, p-value = 0.1409 thus P>0.05. The result indicate that the two areas are similar in terms of browse availability

Table 10: Browse difference for Ngulia and IPZ low use area

Habitat	N	Mean Volume (M^3) µ	Std. Error Mean
Ngulia	30	107.3	15.0
Low use	14	47.6	11.6

4.1.9 Comparison between plant species diversity

Simpsons diversity indices for all species and preferred species for Ngulia, IPZ high use area and IPZ low use area were calculated as presented in the table below

Table 11: Comparison between diversity for all species and preferred species in Ngulia and IPZ

Sites/species category	Simpson's dominance index l	Simpson"s diversity index
IPZ all species	0.04	0.96
Ngulia all species	0.09	0.91
IPZ preferred species	0.16	0.84
Ngulia preferred species	0.22	0.78
High use area all species	0.11	0.89
Low use area all species	0.075	0.92
High use area preferred species	0.11	0.89
Low use area preferred species	0.27	0.73

Species diversity dictates the uniqueness of a community structure in a biological context. A community is said to have a high species Diversity of species in a community is regarded as high if many similarly or virtually similarly plentiful species are found. Conversely, low diversity species community is the one with, few species in abundance. Simpsons diversity index rating of 0 to 1 apportions higher diversity to higher scores. The results indicate that IPZ area has higher diversity of all species and higher diversity of preferred plant species as compared to Ngulia. IPZ low use area has a higher diversity index of all species as compared to the high use area. The result also shows that the diversity of preferred plant species was higher in the high use area than the low use area of the IPZ.

4.1.10 Comparison between community similarity for Ngulia and IPZ

The Sorensen coefficient was calculated to determine if there was any similarity in all species and preferred plant species composition in Ngulia and IPZ and within the IPZ high use and low use areas (Table 11).

Table 12: Comparison between community similarity for all and preferred sps in Ngulia and IPZ

Site	**Sørenesen coefficient for all species**	**Sørenesen coefficient for preferred species**
IPZ and Ngulia	0.66	0.66
High use area and low use area	0.67	0.67

Sorensen's coefficient values range from 0 (no similarity – when no species are found in both communities) to 1.0 (complete similarity – when all species are found in both communities). The result above indicate a similarity coefficient 0.66 for Ngulia and IPZ all species and 0.66 for preferred species. It also shows that the high use area and low use area have equal similarity coefficients for all species and preferred species.

4.2 Distribution patterns and home range

4.2.1 Distribution patterns and home ranges of Ngulia and Nakuru male and female rhinos

The size of all seasons home ranges, as well as home range establishment patterns of rhinos, were highly variable among source areas and sexes (Table 12). A paired sample t-test was conducted to compare the difference in the sizes of 95% MCP of Ngulia male rhinos for all seasons and 95% MCP of Nakuru male rhinos for all seasons. There was a significant difference in the 95% MCP (123 km^2) for Ngulia male rhinos for all seasons and 95% MCP (521 km^2) for Nakuru male rhinos for all seasons, $t(1) = 67.333$, $P = 0.009454$ with $P<0.05$. The result shows that size of 95% MCP of all seasons male rhino home ranges (123 km^2) varied significantly for Ngulia sourced males to 521 km^2 (Nakuru sourced male). A paired sample t-test was also conducted to compare the difference in the sizes of 95% MCP of Ngulia female rhinos for all seasons and 95% MCP for Nakuru female rhinos for all seasons. There was a significant difference in the 95% MCP (137.9 km^2) for Ngulia female rhinos for all seasons and 95% MCP (567 km^2) of Nakuru female rhinos for all seasons, $t(1) = 87.687$, $P = 0.00726$ with $P<0.05$. The result indicate that the home range sizes of 95% Kernel polygons of all seasons female rhino home ranges varied significantly from 137.9 km^2 (Ngulia sourced females) to 567 km^2 (Nakuru sourced females). The Kernel approach indicated that rhinos sourced from Nakuru ranged further from their release sites and had large home ranges as compared to those sourced from Ngulia (Figure 6&7) with males and females from each area exhibiting similar distribution. A paired sample t-test was conducted to compare the difference in the sizes of 50% MCP of Ngulia male rhinos for all seasons and 50% MCP of Nakuru male rhinos for all seasons. There was no significant difference in the 50% MCP (15km^2) of Ngulia male rhinos for all seasons and 50% MCP (89km^2) of Nakuru male rhinos for all seasons, $t(1) = 5.4348$, $P = 0.1158$ with $P>0.05$. Althogh the results indicate no significant difference in the core areas, Ngulia sourced male rhinos established three distinct core areas (50% Kernel polygons - 15km^2) as compared to Nakuru sourced males which established two distinct core areas – 89km^2, between which they either regularly switched, or which they established at different times of the survey. On the other hand, a paired sample t-test was also conducted to compare the difference in the sizes of 50% MCP of Ngulia female rhinos for all seasons and 50% MCP of Nakuru female rhinos for all seasons. There was a significant difference in the 50% MCP (8.2 km^2) of Ngulia female rhinos for all seasons and 50% MCP (119.3 km^2) of Nakuru female rhinos for all seasons, $t(1) = 38.679$, $P = 0.01646$ with $P<0.05$. The results indicate that Ngulia sourced female rhinos had a smaller home range as compared to Nakuru female rhinos. Ngulia rhinos also established only one distinct core areas (50% Kernel polygons – 8.2km^2) as compared to Nakuru sourced females which established three distinct core areas – 119.3 km^2, during the survey

Table 13: Comparison of home ranges of both male and females rhinos from Nakuru and Ngulia

Total Home range	**Males**	**Females**
All season Ngulia sourced male and female rhinos		
95% Kernel (KM^2)	123	137.9
50% Kernel (KM^2)	15.0	8.2
Number of core areas	3	1
All season Nakuru sourced male and female rhinos	**Males**	**Females**
95% Kernel (KM^2)	521	567
50% Kernel (KM^2)	89	119.3
Number of core areas	2	3

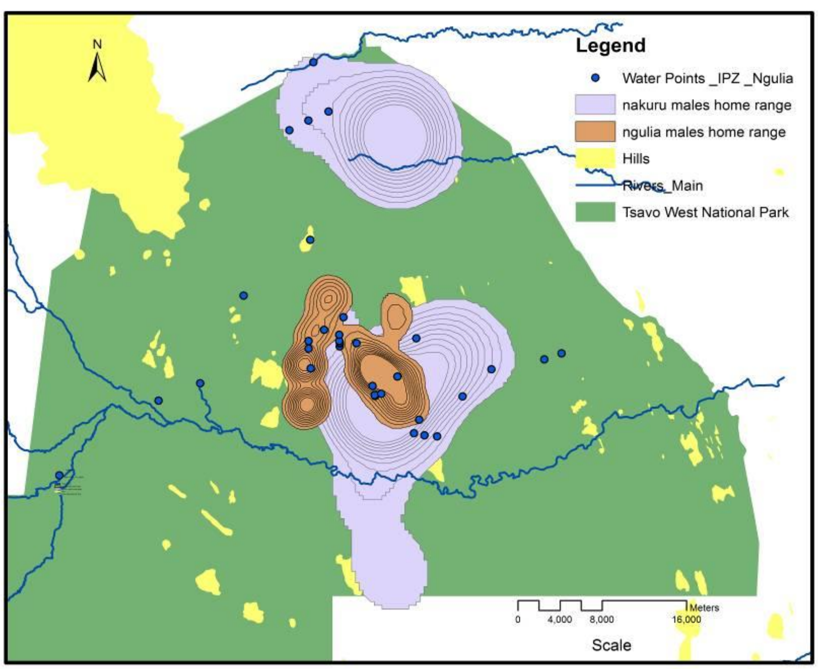

Figure 6: Home ranges of male rhinos sourced from Nakuru and Ngulia

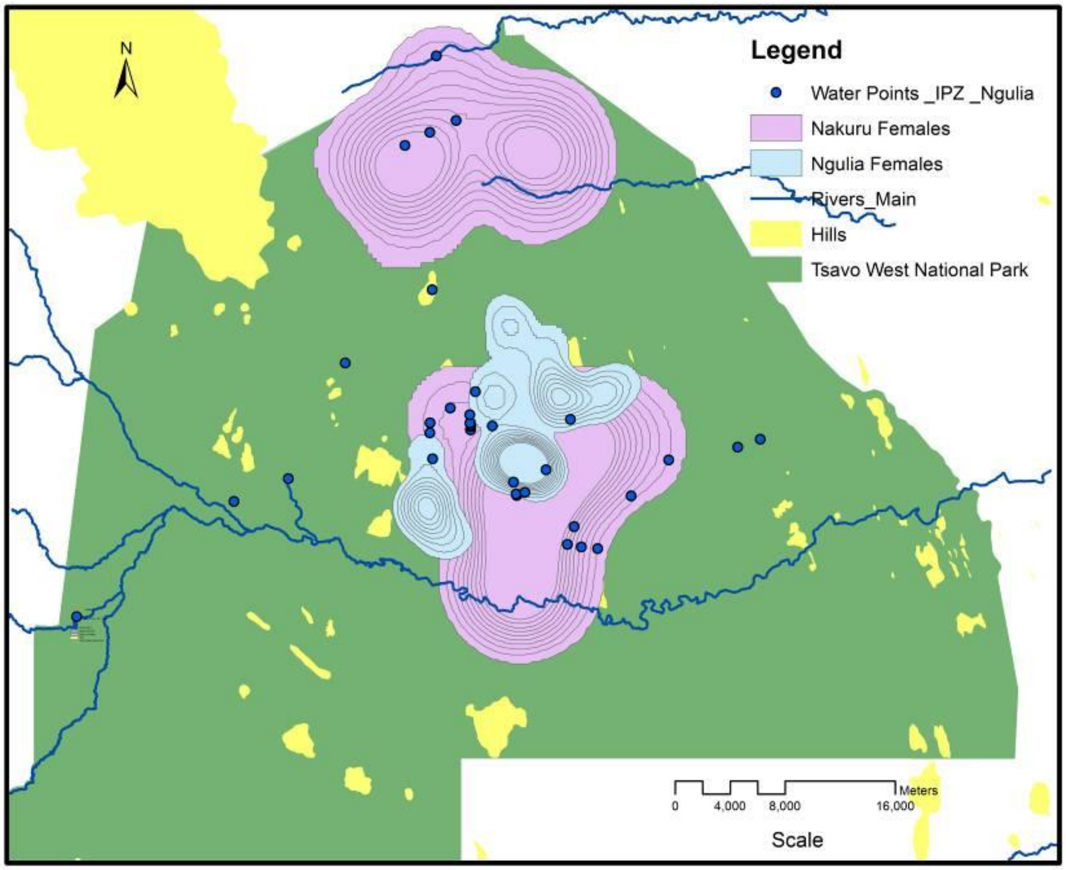

Figure 7: Home ranges of female rhinos sourced from Nakuru and Ngulia

4.2.2 Dry and wet season distribution and home ranges of all Ngulia sourced rhinos

Home ranges, as well as home range establishment patterns of rhinos, varied among source areas and seasons. A paired sample t-test was conducted to compare the difference in the sizes of 95% MCP of Ngulia rhinos during dry season and 95% MCP of Nakuru rhinos during dry season. There was a significant difference in the 95% MCP (151.3 km^2) for Ngulia rhinos during dry season and 95% MCP (670.4 km^2) for Nakuru rhinos during dry season, $t(1) = 27.689$, $P = 0.02298$ with $P<0.05$. This indicate that the Ngulia rhinos had significantly small home range sizes at 95% MCP during the dry season where as the Nakuru rhinos had larger home range sizes at 95% MCP during the dry season. A paired sample t-test was also conducted to compare the difference in the sizes of 95% MCP for Ngulia rhinos during wet season and 95% MCP for Nakuru rhinos during wet season. There was a significant difference in the 95% MCP (143.2 km^2) for Ngulia rhinos during wet season and 95% MCP (696.4 km^2) for Nakuru rhinos during wet season, $t(1) = 126.73$, $P = 0.005023$ with $P<0.05$. This also indicate that the Ngulia rhinos had significantly small home range sizes at 95% MCP during the wet season where as the Nakuru rhinos had larger home range sizes at 95% MCP during the wet season. The 95% Kernel polygons of all rhino's home ranges varies from 143.2 km^2 (Ngulia sourced wet season) to 696.4 km^2 (Nakuru sourced wet season) (Table 13).

A paired sample t-test was conducted to compare the difference in the sizes of 50% MCP of Ngulia rhinos during dry season and 50% MCP for Nakuru rhinos during dry season. There was a significant difference in the 50% MCP (13.1 km^2) for Ngulia rhinos during dry season and 50% MCP (175 km^2) for Nakuru rhinos during dry season, $t(1) = 16.132$, $P = 0.03941$ with $P<0.05$. A paired sample t-test was also conducted to compare the difference in the sizes of 50% MCP of Ngulia rhinos during wet season and 50% MCP of Nakuru rhinos during wet season. There was a significant difference in the 50% MCP (7.5 km^2) for Ngulia rhinos during wet season and 50% MCP (93.4 km^2) for Nakuru rhinos during wet season, $t(1) = 16.761$, $P = 0.03794$ with $P<0.05$. The Kernel approach indicated that rhinos from Ngulia exhibited a slight decrease in home range sizes during dry and wet season compared to the ones from Nakuru which showed an increase in the home range sizes in both seasons. The results also showed that rhinos from Nakuru still ranged further from their release sites and had large home ranges during both seasons as compared to those sourced from Ngulia (Figure 8&9). Both Ngulia and Nakuru sourced rhinos established two distinct core areas during the dry seasons (50% Kernel polygons) but with different core area sizes of 13.1km^2 and 175 km^2 respectively, between which they either regularly switched, or which they established at different times of the survey. On the other hand, Ngulia sourced rhinos established only one distinct core area of up to 7.5 km^2 during the wet season (50% Kernel polygons) as compared to Nakuru sourced rhinos which established three distinct core areas – 93.4 km^2, during the wet season

Table 14: Comparison between wet and dry season home ranges of rhinos from Ngulia and Nakuru

Dry and wet season Ngulia sourced rhinos	**Dry**	**Wet**
95% Kernel (KM^2)	151.3	143.2
50% Kernel (KM^2)	13.1	7.5
Number of core areas	2	1
Dry and wet season Nakuru sourced rhinos	**Dry**	**Wet**
95% Kernel (KM^2)	670.4	696.4
50% Kernel (KM^2)	175.0	93.4
Number of core areas	2	3

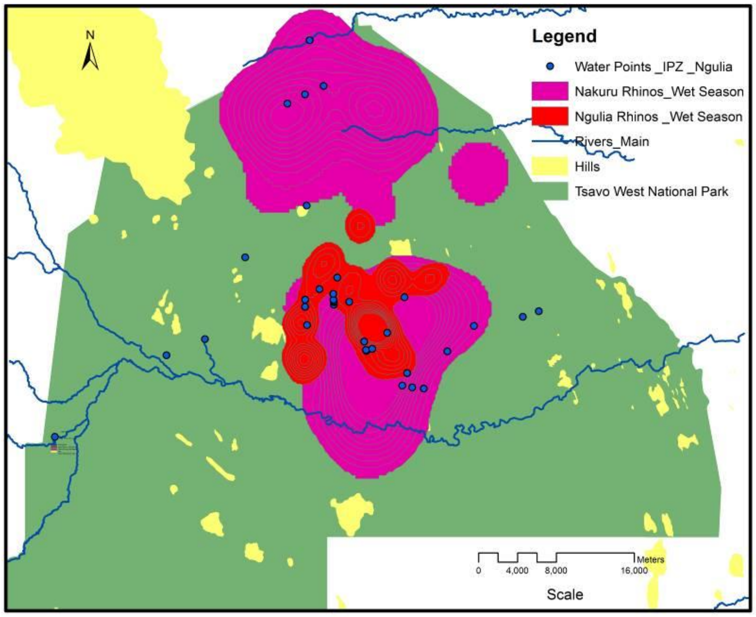

Figure 8: Wet season home range of rhinos sourced from Nakuru and Ngulia

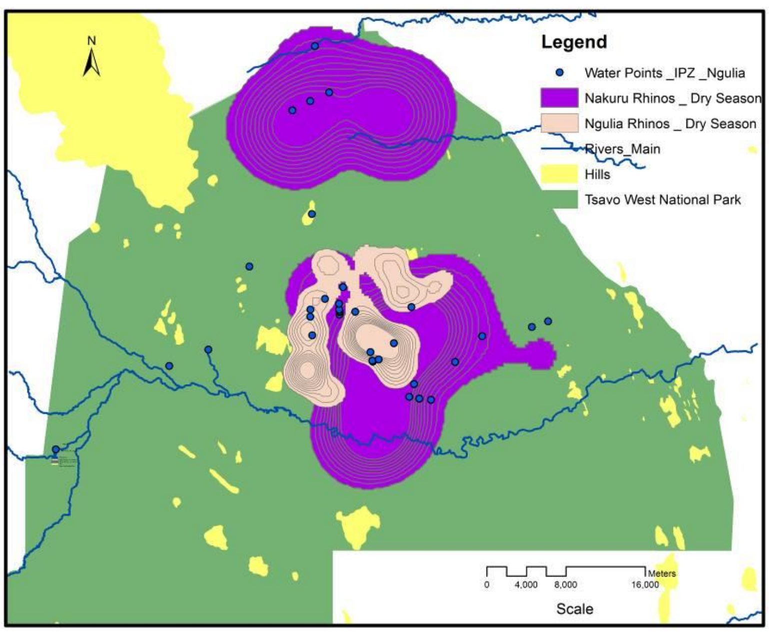

Figure 9: Dry season home range of rhinos sourced from Nakuru and Ngulia

4.2.3 Distribution patterns and home range sizes of all rhinos

By making the source constant, all rhinos seasonal home ranges, as well as home range establishment patterns of rhinos, were not highly variable among seasons and sexes (Table 14). A paired sample t-test was conducted to compare the difference in the sizes of 95% MCP for all rhinos for dry season and 95% MCP for all rhinos for wet season. There was no significant difference in the 95% MCP (372.2 km^2) for all rhinos in dry season and 95% MCP (317.2 km^2) for all rhinos in wet season, t(1) = 3.5, P = 0.1772 with P>0.05. The results show that the sizes of 95% MCP of all dry season rhino home ranges varies from 372.2 km2 (during the dry season) to 317.2 km2 (during the wet season) but the variation in sizes were not significant. A paired sample t-test was also conducted to compare the difference in the sizes of 95% MCP of male rhinos for all seasons and 95% MCP of all female rhinos for all season. There was a significant difference in the 95% MCP (275.4 km^2) of all male rhinos for all seasons and 95% MCP (369.0 km^2) of female rhinos for all seasons, t(1) = 71, P = 0.008966 with P<0.05. The 95% Kernel polygons results indicate that the IPZ female rhinos had a wider home range size at 95% MCP than males for the combined seasons. The Kernel approach indicate that rhinos established a bigger home range during the dry seasons as compared to the wet season and ranged further from their release sites during the wet season than during dry season but the difference were not significant. Females ranged further than males during the both seasons (Figure 10&11). A paired sample t-test was also conducted to compare the difference in the sizes of 50% MCP of all rhinos during the dry season and 50% MCP for all rhinos during the wet season. There was no significant difference in the 50% MCP (24.1km^2) for rhinos during the dry season and 50% MCP (20.2 km^2) for rhinos during the wet season, t(1) = 2.2188, P = 0.2696 with P>0.05. A paired sample t-test was again conducted to compare the difference in the sizes of 50% MCP for all male rhinos for all seasons and 50% MCP for all female rhinos for all seasons. There was no significant difference in the 50% MCP (24.3km^2) for male rhinos for all seasons and 50% MCP (24.1 km^2) for female rhinos for all seasons, t(1) = 1.2222, P = 0.4365 with P>0.05. The analysis showed that rhinos established only one distinct core areas (50% Kernel polygons) in both wet and dry season and in both sexes

Table 15: Comparison between males and females rhinos and seasonal home range sizes

Dry and wet Season all IPZ rhinos	Dry	Wet
95% Kernel (KM^2)	372.2	317.2
50% Kernel (KM^2)	24.1	20.2
Number of core areas	1	1
All season IPZ rhinos	**Males**	**Females**
95% Kernel (KM^2)	275.4	369.0
50% Kernel (KM^2)	24.3	24.1
Number of core areas	1	1

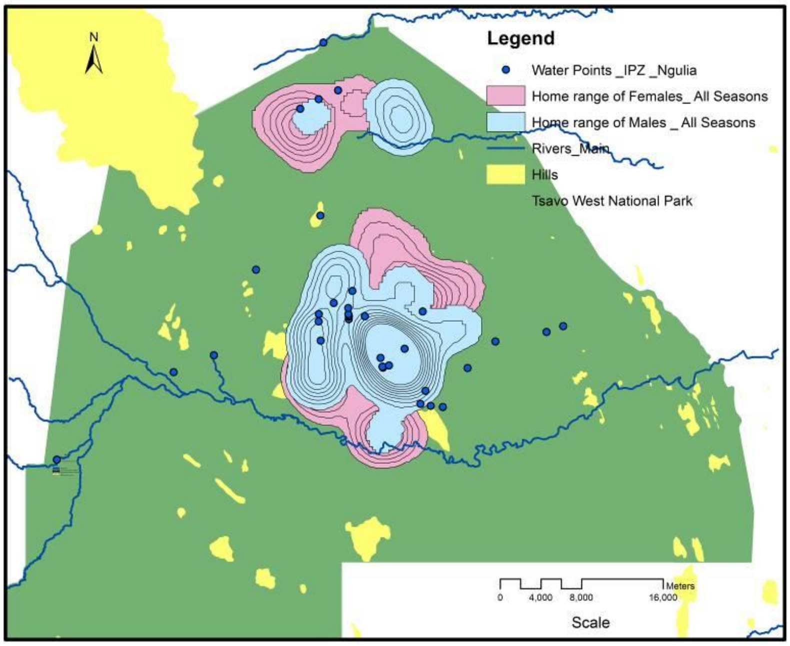

Figure 10: All Season home ranges of Male and Female rhinos in the IPZ

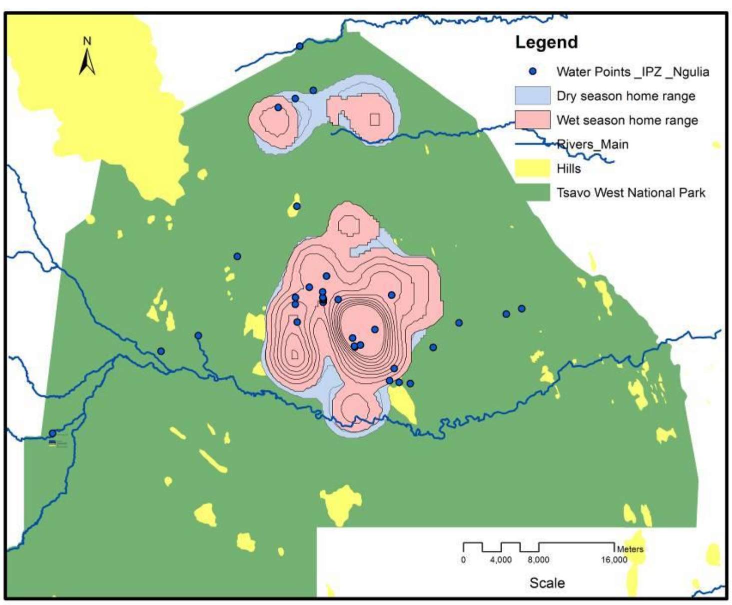

Figure 11: Dry and Wet season home range of all rhinos in the IPZ

5 CHAPTER FIVE: DISCUSSION CONCLUSIONS AND RECOMMENDATIONS

5.1 Discussion

Black rhinos, like all other animals, have their distribution patterns and home ranges predisposed by a variety of set of ecological factors which determine their utilization of habitat use and dictates their manifestation in a certain area. However almost nothing is known of their home range sizes and how they are affected by browse availability and suitability after translocation. This study focused mainly on the habitat variables and in particular browse availability, species diversity and suitability/preference and its influence on the rhino home range sizes and distribution.

5.1.1 Home Range

The size of all seasons home ranges, as well as home range establishment patterns of rhinos, were highly variable among source areas and sexes. The 95% MCP of all seasons male rhino home ranges (123 km^2) varied significantly for Ngulia sourced males to 521 km^2 (Nakuru sourced male). It was also found out that the home range sizes of 95% Kernel polygons of all seasons female rhino home ranges varied significantly from 137.9 km^2 (Ngulia sourced females) to 567 km^2 (Nakuru sourced females). The 50% MCP (15km^2) of Ngulia male rhinos for all seasons and 50% MCP (89km^2) of Nakuru male rhinos for all seasons, showed no significant difference. Althogh the results indicate no significant difference in the core areas, Ngulia sourced male rhinos established three distinct core area as compared to Nakuru sourced males which established two distinct core areas. This indicate that Nakuru males having been translocate in after the Ngulia males were being pushed by Ngulia males from the preferred areas. On the other hand the 50% MCP (8.2 km^2) for Ngulia female rhinos for all seasons and 50% MCP (119.3 km^2) for Nakuru female rhinos for all seasons showed a significant difference This indicate that Ngulia sourced female rhinos had a smaller home range as compared to Nakuru female rhinos. Ngulia female rhinos also established only one distinct core areas at 50 % MCP as compared to Nakuru sourced females which established three distinct core areas at 50 % MCP. This again could be the result of either competition for browse resources or result of differences in translocation periods that gave the Ngulia female rhinos an upper advantage of establishing themselves in areas with higher available browse resources.

These results agrees with studies done before on rhinoceros indicating that home ranges are highly flexible. (Frame, 1980); Home ranges in the Tsavo West National Park - IPZ of 7.5 – 696.4 km^2 are larger compared to other areas. Inn some way this shows a low browse availability or low preferred browse for rhinos, but it is likely that other factors were in play for the higher home range sizes. Lent and Fike (2003) studied ranging behaviour of an increasing rhino population in a Reserve in South Africa. According to studies, these authors found great variances in individual home range size (affected by social factors) and rhinos shifting home ranges over time. The authors report core areas (50% Kernel polygons) between 1.8 km^2 and 9.9 km^2. It has been noted that Namibian black rhinos exhibits the largest home range sizes (Loutit 1984, Berger and Cunningham 1995). Accordingly, home ranges of most individuals from studies are among the largest recorded for the species. This is because of the sparse distribution of browse resources. Slight seasonal effects on home range and core area size or seasonal movements of all rhinos were observed. But greater effects were observed in sexes with females having larger home ranges than males. Several studies have shown seasonal changes of home ranges of reintroduced large herbivores Linnaeus 1758

The 50% MCP (13.1 km^2) of Ngulia rhinos during dry season and 50% MCP (175 km^2) of Nakuru rhinos during dry season showed a significant difference in sizes. Similarly, there was a significant difference in the 50% MCP (7.5 km^2) of Ngulia rhinos during wet season and 50% MCP (93.4 km^2) of Nakuru rhinos during wet season. The Kernel approach indicated that rhinos from Ngulia exhibited a slight reduction in range during wet period compared to the ones from Nakuru which showed an increase in the home range sizes. The results also showed that rhinos from Nakuru still ranged further from their release sites and had large home ranges during both seasons as compared to those sourced from Ngulia. As acclimatisation includes seasonal, browse and climatic changes (Hart 1957), the differences observed in this study were some indicators for the acclimatisation of Nakuru rhinos to food resources in the IPZ. Wildlife managers of black rhinos should consider the dimension of browse assessment before translocation.

5.1.2 Browse availability and suitability

The Kernel approach indicated that rhinos sourced from Nakuru ranged further from the core area and had large home ranges as compared to those sourced from Ngulia with males and females from each area exhibiting similar distribution. Studies have proved that there are many factors that determine black rhino range extent. Rhino home range areas may vary with an animal's Individual rhino requirements may to some extent determine its range extentwith greater extent exhibited when requirements such as browse and water are wide spread (Mukinya 1973). Browse availability results indicated that Ngulia had higher browse availability for all plant species and for preferred plant species than the IPZ. The higher browse in Ngulia could be attributed to the reduction of numbers of elephants, buffaloes, rhinos and the expansion of the sanctuary. On the other hand, the results indicated that IPZ area had a higher diversity of all species and a higher diversity of preferred plant species than Ngulia where as Ngulia and IPZ were found to have a slight similarity in all species composition and preferred species. Higher diversity of plant species and more so of preferred plant species in the IPZ could explain the differences in home range sizes for Ngulia and Nakuru rhinos. The low range extent exhibited by Ngulia rhinos may perhaps be attributed to Ngulia rhinos being released in an area almost similar to their previous home in plant species composition where as Nakuru rhinos found themselves in unfamiliar habitat hence their higher home range sizes attributed to acclimatization effects (Hart 1957), From the study, it was also found out that there was no significant difference in the BA for high use and low use areas of the IPZ. This suggested that rhino home range sizes and distribution in the IPZ was not influenced by browse availability since the two areas had similar browse availability. Similarly, the study found out that the low use area had a higher diversity of all species than the high use area. It was also found out that there was a slight similarity in the composition of all species in the two areas indicating no influence of of plant species composition and diversity of all plant species on distribution of rhinos. BA of the preferred plant species for high use and low use areas of the IPZ were found to be similar whereas the high use area was found to have a higher diversity of preferred plant species as compared to the low use area of the IPZ. However, the high use area and low use areas were found to be similar in the composition of preferred plant species. The results suggest that the browse availability of preferred plant species alone could not have influenced rhino home range sizes and distribution. The high diversity of preferred plant species in the high use area could be the factor the influenced rhino distribution in this area.

From the study, it was found out that Ngulia and high use area of the IPZ differed in the BA of preferred plant species whereas Ngulia and low use area of the IPZ showed no difference in the BA of preferred plant species. On the other hand it was found out that the high use area of the IPZ had a higher diversity of preferred plant species as compared to Ngulia whereas Ngulia had a higher diversity of preferred plant species as compared to the low use area of the IPZ. The results suggests that although Ngulia had more browse availability of preferred plant species than the IPZ high use area, the high use area had a higher score in terms of preferred plant species diversity hence more preferred by rhinos . The result also suggests that although Ngulia and the low use area of IPZ had similar BAs of preferred plant species, the low use area had a lower score in terms of preferred plant species diversity hence less preferred by rhinos. This again explains the role of higher species diversity in influencing rhino home ranges and distribution in an area

5.2 Conclusion

This study has shown that home range sizes and distribution patterns of rhinos in the IPZ varied among sexes, seasons and source areas. From this study, no difference in home range sizes and distribution of all rhinos in the IPZ for the dry and wet seasons was evident. Female rhinos ranged further and had bigger home ranges as compared to male rhinos in the IPZ. Nakuru rhinos ranged further from their release sites and had large home ranges during both seasons as compared to rhinos sourced from Ngulia. This was exhibited in both males and females from the respective sources. The larger home ranges of Nakuru Rhinos and lower home ranges of Ngulia Rhinos has shown that rhinos will range further and have larger home ranges when translocated and released in an area with different habitat from their original source and vise versa. Tthe larger home ranges of Nakuru rhinos could also be attributed to differences in translocation periods. Nukuru rhinos were translocated in an area already occupied by Ngulia rhinos and the could have found areas with preferred browse already taken up by Ngulia rhinod hence their large home ranges Management implication of this is that thorough habitat assessment among other assessment need to be conducted at the source area and destination area before Rhino translocation. This will assist in predicting movement patterns and guide in resource planning for security and monitoring.

. The degree of utilization of the different areas of the IPZ varied from areas with high to low browse availability, high to low preferred browse availability, high to low species diversity and high to low preferred species diversity, this is of benefit to rhinos as it states that the suitability of an area for rhinoceros not only hinges on the amount of browse. Instead, the diversity of all species and more so of rhino preferred plant species of various communities may be of value too. It is evident that black rhinos prefer areas with higher diversity of plant species and more so of preferred plant species. This suggests that an increase or decrease in the diversity of plant species and of preferred plant species would influence home range sizes and distribution patterns and hence increase or decrease the carrying capacity for black rhinos. These factors among others need to be put into consideration by wild life managers when planning for translocation of black rhinos from one area to the other.

5.3 Recommendations

1. There is need to expand the study to the second source area to enable complete comparison of the two areas
2. Other than browse availability and suitability, other factors such as availability of drinking water, relief, human activities in an area, terrain and population of other animal species need to put into consideration in determining factors that can influence rhino distribution and home range in an area.
3. Thorough habitat assessments that involves vegetation variables such as plant cover, plant species density, plant species diversity and community similarity of the source and recipient area should be conducted for comparison before any translocation is done
4. Adequate security and monitoring resources are paramount for the conservation success of free ranging rhino in the IPZ
5. Separate release sites should be considered when translocating rhinos from different sources and at different time intervals
6. Continued research and monitoring of the rhinos in Ngulia and the free ranging rhinos in the IPZ is important in further understanding their population growth and performance for continued improvement of the populations
7. Improved funding, training and infrastructural support for the security, research and monitoring teams in Ngulia and IPZ

8. Regular audit of the rhino population in Ngulia and IPZ to be done every after two years of continued monitoring

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